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OFFICE OF THE SECRETARY

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January 6, 1994

By Hand

Mr. William F. Caton
Acting Secretary
Federal Communications Commission
1919 M Street, NW
Washington, DC 20554

Re: Ex Parte Presentation
CC Docket No. 92-297
Local Multipoint Distribution Service

Dear Mr. Caton:

On behalf of Suite 12 Group ("Suite 12"), petitioner in the above-referenced rulemaking proceeding, enclosed please find two (2) copies of a technical study titled "Frequency Reuse in the Cellular LMDS" which was jointly prepared by Eric N. Barnhart, Chief, Communications and Networking Division, Information Technology and Telecommunications Laboratory, Georgia Institute of Technology, Roger L. Freeman, Roger Freeman Associates and Suite 12 inventor-engineer Bernard B. Bossard. This study examines the system geometry of Suite 12's innovative technology for Local Multipoint Distribution Service, and demonstrates how the spectrally efficient technology uses and reuses frequencies in adjacent cells, without creating interference between cells, as it provides high quality video transmission.

Please place these two copies of this technical study in the above-referenced docket. Any questions regarding this study should be directed to the undersigned.

Sincerely,

Michael R. Gardner

Michael R. Gardner
Charles R. Milkis
William J. Gildea III
Counsel for Suite 12 Group

Enclosures

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January 6, 1994

By Hand

Dear: Chairman Hundt
Commissioner Quello
Commissioner Barrett
Commissioner Duggan

Re: CC Docket No. 92-297
Local Multipoint Distribution Service
"Frequency Reuse in the Cellular LMDS"

On behalf of Suite 12 Group ("Suite 12"), enclosed for your review is a technical study entitled "Frequency Reuse in the Cellular LMDS" which demonstrates the Suite 12 technology's unique ability to use and reuse frequency within designated cell areas. As a result, the Suite 12 technology is a spectrally efficient means of providing a competitive alternative to cable and other voice and data services.

This study was jointly prepared by Eric N. Barnhart, Chief, Communications and Networking Division, Information Technology and Telecommunications Laboratory, Georgia Institute of Technology, Roger L. Freeman, Roger Freeman Associates and Suite 12 inventor-engineer Bernard B. Bossard. It demonstrates how Suite 12's system utilizes spacial separation, cross-polarization, frequency interleaving and antenna discrimination to provide a high quality picture which greatly surpasses that of standard, wireline cable, without creating co-channel interference among cells.

In view of the conclusions contained in this technical study and in other documents recently placed in the record by Suite 12, and in view of the Commission's own findings set forth in its NPRM released early in 1993, the LMDS rulemaking record overwhelmingly supports the Commission's previously proposed reallocation of the largely unused 28 GHz band for the pro-competitive LMDS, with the issuance of two 1 GHZ licenses per service area.

Sincerely,

Michael R. Gardner

Michael R. Gardner
Counsel for Suite 12 Group

Enclosures
cc Acting Secretary William F. Caton
(for inclusion in LMDS Rulemaking Record)

FREQUENCY REUSE IN THE CELLULAR LMDS

by

• ***Eric N. Barnhart*** •
Chief, Communications and Networking Division
Information Technology & Telecommunications Laboratory
Georgia Institute of Technology

• ***Roger L. Freeman*** •
Roger Freeman Associates

• ***Bernard B. Bossard*** •
Suite 12 Inventor-Engineer

FREQUENCY REUSE IN THE CELLULAR LMDS

I. Introduction

The Suite 12 Group's "CellularVision Technology for the Local Multipoint Distribution Service" ("LMDS") currently provides 49 channels of television or an expanded equivalent mixture of television, video teleconferencing, voice and data transmission services in a 1 GHz bandwidth in the range of 27.5 to 29.5 GHz. Suite 12's technology provides such services with a cellular architecture of contiguous geographic coverage areas, "cells," having nominally a circular area with a diameter of approximately 6 miles. The system is highly spectrum-efficient, as its 1 GHz of frequency bandwidth is reused fully within every cell, even adjacent cells. To accomplish this spectrum efficient operation without creating interference among cells, a set of interference suppression strategies are employed. In this paper we establish the carrier to interfering signal ratio (C/I) necessary for video transmission and demonstrate how it is accomplished within the cellular LMDS design.

II. LMDS Signal

Suite 12's technology for LMDS uses a 100 Watt (20 dBW) continuous wave transmitter for all 49 channels, operating on either the 27.5 to 28.5 GHz or the 28.5 to 29.5 GHz frequency band. Interleaving of diagonal adjacent cell sites causes the actual channel transmission frequencies to differ by 10 MHz from each other, as will be discussed in a later section. To operate the TWTA in a linear manner, minimizing the intermodulation distortion in individual channels, a 7 dB linearity backoff is employed. Accordingly, the total output of the tube is approximately 20 Watts (+13 dBW). Since this power is divided among 49 individual channels, the per channel power level is 0.4 Watts (-4 dBW). A transmit antenna having +12 dBi gain is employed, resulting in an effective isotropic radiated power (EIRP) of +7 dBW/channel, when an allowance for an additional 1 dB of line loss between the transmitter and antenna is provided.

The path loss for a 3-mile radial maximum range is -135.1 dB. The receive antenna gain is +32 dBi. These values are summarized in **Table A**.

Table A. LMDS Link Calculation Under Clear Weather Conditions

1)	100 W transmitter (49 channels)	+20 dBW
2)	7 dB Linearity Backoff	+13 dBW
3)	49 Channels	- 4 dBW/channel
4)	1 dB line loss	- 5 dBW/channel
5)	+12 dBi Transmit Antenna Gain	+ 7 dBW EIRP
6)	Path loss (3 mile maximum radial distance)	-135.1 dB @ 28 GHz
7)	Isotropic Receive Level 5)+6) =	-128.1 dBW
8)	Receive antenna gain	+32 dBi[1]
9)	Receive carrier level, C = 7)+8)	-96.1 dBW/channel

Receiver Bandwidth, by Carson's Rule:

Peak-Peak Deviation = 10.6 MHz

2 x Baseband = 2 x 4.2 = 8.4 MHz

Bandwidth = 10.6 + 8.4 = 19.0 MHz

Note that since the Suite 12 video modulator uses overdeviation and limits the transmitted bandwidth to 18 MHz per channel, the subscriber receiver is likewise

[1] Suite 12 Group has evaluated two receive antennas for the LMDS application: Planar Array (Gain = +31 dBi) and Parabolic (Gain = +32 dBi).

designed. Thus, even though the Carson's Rule approximation gives a bandwidth of 19 MHz per channel, the true receiver noise bandwidth of 18 MHz per channel must be used to calculate carrier to noise ratio.

Using the receiver noise figure of 6 dB,

Receiver Thermal Noise Floor = N = -204 dBW/Hz + 6 dB + 10 log (18×10^6)

= -125.4 dBW/channel

Carrier to Noise Ratio, C/N = -96.1 dBW - (-125.4 dBW) = 29.3 dB

The LMDS Signal to Noise ratio is calculated using the C/N and the FM receiver transfer function according to **Table B**.

Table B. LMDS Signal to Noise Ratio (S/N)

$$S/N\ (NTSC) = C/N + 10\log 3(\text{delta } f/fm)^2 + 10\log(Bif/2Bv) + W + CF$$

where:

delta f = peak composite video deviation (5.3 MHz)

fm = highest baseband frequency (4.2 MHz)

Bv = video noise bandwidth (4.2 MHz)

Bif = IF noise bandwidth (18 MHz)

W = emphasis + NTSC weighting = 12.8 dB

CF = rms to peak-peak luminance signal conversion factor

= 6 dB

Thus, for LMDS:

$$S/N = 29.3 + 10\log 3(5.3/4.2)^2 + 10\log(18/8.4) + 12.8 + 6 \text{ (in dB)}$$

$$= 29.3 + 6.8 + 3.3 + 12.8 + 6$$

$$= 58.2 \text{ dB}$$

For rainfall attenuation (see Appendix A), the S/N is reduced by 13 dB or:

S/N = 45.2 dB (RAIN)

In order to relate S/N to viewer picture quality we use the quality factor, Q, numerically equal to the CCIR number grading.[2] Thus, Q = 5 corresponds to excellent, Q = 4 is good, Q = 3 is fair, and so forth. This interpretation of Q is not consistently defined throughout the industry. A Q of 5 is considered in some cases to be representative of a "studio quality" picture without any apparent defects. The measure of Q = 4 by the definitions used in this paper corresponds to a picture substantially better than available on a cable system. Note the proposed FCC cable standard is S/N = 43 dB with Q = 3.5.

The subjective picture quality as a function of S/N is, from the Sarnoff Report [9], repeated here in **Table C**.

Table C. Signal to Noise Ratio (S/N) for Various Picture Quality Levels (Q)

S/N (dB)	Picture Quality (Q)
40.0	3.0
41.0	3.2
42.0	3.3
43.0	3.5
44.0	3.7
45.0	3.8
46.0	4.0
52.0	5.0

In this rating scale, a Q = 5 is perceived by a viewer as an essentially perfect, studio quality picture, requiring S/N of 52 dB. Thus, it can be seen that, based on the link budgets, the LMDS design well exceeds this level in clear weather, with a S/N = 58 dB, and even under rain conditions, at 45 dB, it maintains a good quality signal.

---

[2] Reference CCIR Report 500-4, 1990 Plenary Assembly.

The above values assume that the TWT Amplifier in the 49-channel transmitter operates with essentially no intermodulation distortion at the 7 dB backoff level used in the link budget of **Table A**. This assumption is essentially equivalent to the assumed use of a TWT linearizer to apply pre-distortion in the video modulator to eliminate nonlinear distortion at the 7 dB backoff level. If no pre-distortion is applied at the 7 dB backoff level, it can be shown that an effective carrier-to-interference ratio (C/I) of 21 dB would be introduced at the transmitter amplifier. With a C/I of 21 dB, a Q of 4 results, which is equivalent to an S/N of 46 dB. Using a linearizer, the C/I due to intermodulation in the transmitter would improve to 28 dB, resulting in a Q of 5, which is equivalent to an S/N of 52 dB. Note that this makes the effect of intermodulation insignificant relative to the S/N of 45 dB for the most intense rain-faded conditions which occur less than 0.1 percent of the time and only in the fringe areas.

III. Picture Quality in the Presence of Co-channel Interference

Picture quality in the presence of co-channel interference is also a subjective measure, normally determined by surveying responses of lay viewing panels. Q is a function of:

- Coding system (NTSC, PAL, SECAM, etc.)
- Picture content
- Subjective response of panel members
- Signal to noise ratio
- Carrier to interference ratio

Below, we calculate the required isolation (protection ratio) between the desired and interfering signals using the methods adopted by the CCIR [12], for standard 525 line M/NTSC video.

$$PRo(dB) = 16.9 - 8.7\log(Iu) - 20\log(Dpp/12)$$

where:

PRo = Required co-channel protection ratio

Dpp = peak-peak deviation (MHz) = 10.6 MHz

Iu = (5-Q)/(Q-1) for $1 < Q < 5$

Q = picture quality

Substituting in values of Q from 2 to 4.5, the required co-channel protection ratios are as shown in **Table D** with the respective picture quality levels.

Table D. Subjective Quality of Television Picture with Co-Channel Interference

PRo(dB)	Q	Interference Level	Picture Quality
28.0[3]	5	Imperceptible (interference)	Excellent
25.3	4.5		
22.0	4	Perceptible, but not annoying	Good
19.9	3.5		
18.0	3	Slightly annoying	Fair
16.0	2.5		
13.8	2	Annoying	Poor

The means to accomplish the separation of the signals from multiple LMDS cells, some of which offer overlapping coverage of adjacent geographic areas, are methods similar to those used for other cellular radio systems such as cellular

[3] Approximate—equation invalid as Q approaches 5. Note that Q=5 is considered as $S/N \geq 52$ dB.

telephones, as well as methods whose practicality derives from the millimeter wave frequency band of 27.5 to 29.5 GHz. The principal means to separate signals among the LMDS cells are:

1) **Frequency Bands**: To separate competing service providers in a given area, one provider uses 27.5 to 28.5 GHz and the other uses 28.5 to 29.5 GHz.

The remaining separation methods apply to a given provider:

2) **Polarization Isolation**: Bordering cells employ orthogonally polarized signals, achieved by employing vertically and horizontally polarized antennas. In this diagram the cells are shown as squares, but the cell coverage areas are approximately circular, having diameters equal to the diagonals of the squares shown in **Figure 1**, such that adjacent cell coverage areas somewhat overlap. The measured electrical isolation of vertical and horizontal polarizations for the LMDS receive and transmit antennas are shown in **Table E**. The use of frequency interleaving among cells is treated in the next section.

Table E. Measured Polarization Isolation of LMDS Transmit & Receive Antennas

	Transmit Antenna	Receive Antenna	
Antenna Gain (dBi)	12	32	
V/H Polarization Isolation (dB)	30	37	minimum
		44	typical

The cell template set utilizing polarization isolation and frequency interleaving is shown schematically in **Figure 1**.

V_2	H_2	V_2
H_1	V_1	H_1
V_2	H_2	V_2

Each cell has a diameter of 6 miles with a cell area of 28.3 square miles.

V_1 Indicates vertical linear polarization using odd numbered channels
V_2 Indicates vertical linear polarization using even numbered channels
H_1 Indicates horizontal linear polarization using odd numbered channels
H_2 Indicates horizontal linear polarization using even numbered channels

Figure 1. LMDS cell template utilizing polarization isolation and frequency interleaving to allow frequency reuse within all cells.

This plan has been adopted by Suite 12 because the greatest potential interference can be expected to occur between bordering cells, as shown. The next worst case occurs along diagonal paths, for example V_1/V_2, but these distances of separation are greater than for bordering cells and, more importantly, there is a minimum overlapping coverage area between diagonally adjacent cells, and where the crossover occurs, it is in the receiver antenna backlobe adding additional isolation.

The values given in **Table E** represent the lowest measured isolation values for any orientation of the antenna, and generally the isolation is considerably better. For example, the vertical to horizontal (V/H) polarization isolation of the receive antenna on the boresight heading was measured to be 52 dB. For cell isolation calculations we use the value of the minimum antenna isolation, 30 dB.

One often quoted depolarizing factor is that due to rainfall. Theoretically, a slight polarization shift in the transmitted signal can be induced by rainfall. This is because the rain drops are not perfectly spherical but rather are somewhat flattened as they fall, due to aerodynamic resistance. This causes the water droplets (which have a very high dielectric constant and consequent perturbation of radio signals) to be a little longer in the E field direction of horizontally polarized radio waves than vertically polarized waves.

The depolarizing effect on an otherwise perfectly polarized signal is calculated using Reference [3], page 377. The reference contains this relationship for line of sight paths:

$$XPD = U - V(f)\log(CPA)$$

where

CPA = the rainfall attenuation (in dB) (See Appendix A of this paper)

$U = Uo + 30\log(f)$ (f in GHz)

$Uo = 15$

$V(f) = 20$ for $8 < f < 35$ GHz

Simplifying and using the value of rainfall attenuation derived in Appendix A:

CPA = 13 dB

and $XPD = 58.4 - 20\log(13) = 36.1$ dB

This means that a perfectly horizontally polarized wave would be depolarized to the extent that its vertical component would be 36.1 dB below its principal, horizontal, polarization given a rain attenuation of 13 dB. Likewise, a vertically polarized signal would be depolarized to 36.1 dB. This value is greater than the minimum value of isolation assumed for the antennas and, hence, rain depolarization is not considered significant in the LMDS design.

3) **Frequency Interleaving**: The LMDS television channels are spaced on 20 MHz centers, but filtering results in an active bandwidth of 18 MHz per television channel, resulting in a guard band of 2 MHz between channels. In order to increase the separation of signals from diagonally proximate cells (which have the same polarization), frequency interleaving is employed (**Figure 2**). In this way separation is obtained without any increase in the overall bandwidth required for the transmission of 49 separate FM modulated television programs in diagonally proximate cells due to the degree of isolation between the odd and even numbered channels.

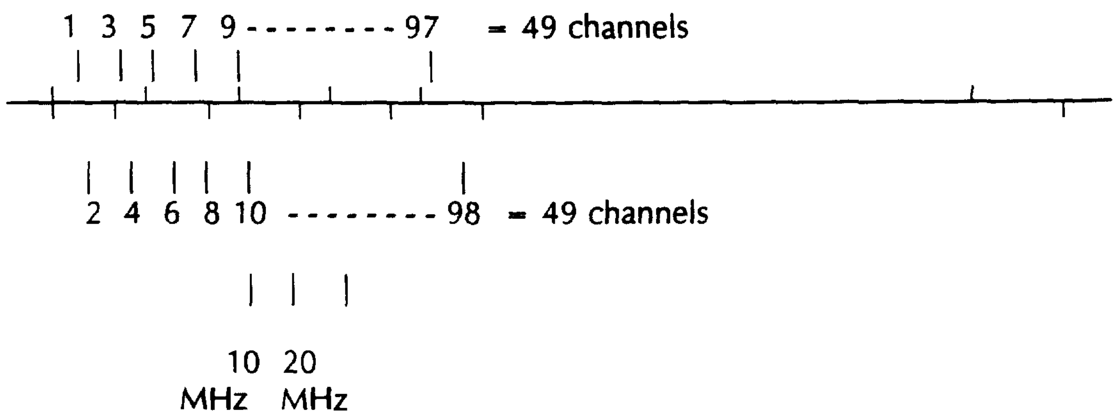


Figure 2. Frequency interleaving plan for two sets of 49 channels in a 1000 MHz transmission bandwidth.

This frequency interleaving between adjacent cells provides a significant portion of the required Protection Ratio (PR) between the desired cell signal and a potential interfering cell's signal (C/I). The amount of protection obtained from interleaving is obtained from Reference [8] using a channel bandwidth of 18 MHz and a channel offset of 10 MHz. Normalized, the frequency offset is 10 MHz/18 MHz = 0.56. Using this value and Figure 11.4, page 361, Reference [8], the additional protection obtained from frequency interleaving is found to be 10.2 dB.

4) **Spatial Isolation Between Cells**: The cells transmit to receivers within their own geographic area, a natural consequence of which is that the strongest reception occurs for the desired, same cell transmitter. Cell sizes as small as 6 miles in diameter are planned and therefore, to be conservative, the calculations of potential interferences are based on this smallest cell size.

To determine the isolation between cells due to spatial separation, we consider four possible cases for relative distance between the desired and undesired LMDS sources. The latitudinal and longitudinal geometries are identical, so we have arbitrarily assigned polarization to latitude, as shown in **Figure 1**. Thus, longitudinally separated cells benefit from both frequency offset and polarization. The cell/cell protection provided by the distance-square-law effect is the same for all directions. If

L = length of side of square in **Figure 1** (4.24 miles here) and

D = cell diameter (6.0 miles here), then:

For latitude and longitude adjacent cells;

$$C/I = (L/2)^2 / (L+L/2)^2$$
$$= 10 \text{ dB}$$

For latitude and longitude non-adjacent cells:

$C/I = (L/2)^2 / (L+L+L/2)2$

$= 14$ dB

For diagonal adjacent cells:

$C/I = (D/2)^2 / (D+D/2)^2$

$= 10$ dB

For diagonal non-adjacent cells:

$C/I = (D/2)^2 / (D+D+D/2)^2$

$= 14$ dB

where "C" is the desired LMDS signal and "I" is the undesired LMDS signal and C/I here is due to the range ratio only.

These interference ratios are the worst-case values, corresponding to full line-of-sight from a receiver at the cell edge to both the wanted and interfering transmissions. Building blockage over the longer, interfering, path will make this a rare occurrence. Furthermore, the narrow beamwidth of the receiver antenna for the majority of subscribers (7 degrees) means that only a small proportion of customers could ever have line-of-sight interference with a diagonally adjacent cell, even on a flat-earth model. It is important to note that for all other subscriber locations outside the area where the receiving antenna is aligned with the interfering antenna, the receiver sidelobe is presented to the interfering antenna and an additional 26 dB of isolation is thereby afforded. For those few subscriber locations for which line of sight to an interfering LMDS hub (15 miles away) exists, a 15-inch, 38 dB gain antenna with a 2.2-degree beamwidth would be employed [[9], page 22].

The percentage of subscribers under this interference condition can be evaluated using **Figure 3**, where the percentage of the area of cell V_2 which presents the subscriber antenna mainlobe to the interfering cell V_2' is given by

Mainlobe percentage = 2.2 degrees / 360 degrees = 0.6%.

For those cases which fall within this 0.6 percent of area, the 2.2-degree beamwidth antenna would be pointed down approximately one degree off boresight to the desired transmitter antenna. This pointing angle for the receiver antenna would present the 3 dB point to the desired transmitter, and a gain of approximately 17 dB below peak to the interfering transmitter. The result is a discrimination against the interference of 14 dB. This is accomplished with no degradation in the picture quality from the desired signal since the added antenna gain due to the narrow beamwidth (2.2 degrees versus 7 degrees) yields an improvement in C/N of 3 dB relative to the 32 dB, 7-degree beamwidth antenna.

Using this value, **Table F** gives a summary of cell-to-cell isolation factors, their combined effects on carrier-to-interference (C/I) ratio and the resulting picture quality (Q). The rows of this table give every possible permutation of adjacent and non-adjacent cells within and outside the mainlobe condition addressed immediately above. It should be noted that for all cases of subscriber location and interference source, a Q approaching 5 is obtainable using various combinations of cell-to-cell isolation factors.

In addition, there are other factors and techniques which can be used to address areas where Q may be less than 5 for any reason. These include:

(a) Blockage and Earth Curvature
(b) Receiver Level Control for FM Threshold Straddling

These are discussed below to determine the anticipated impact on improving C/I and picture quality.

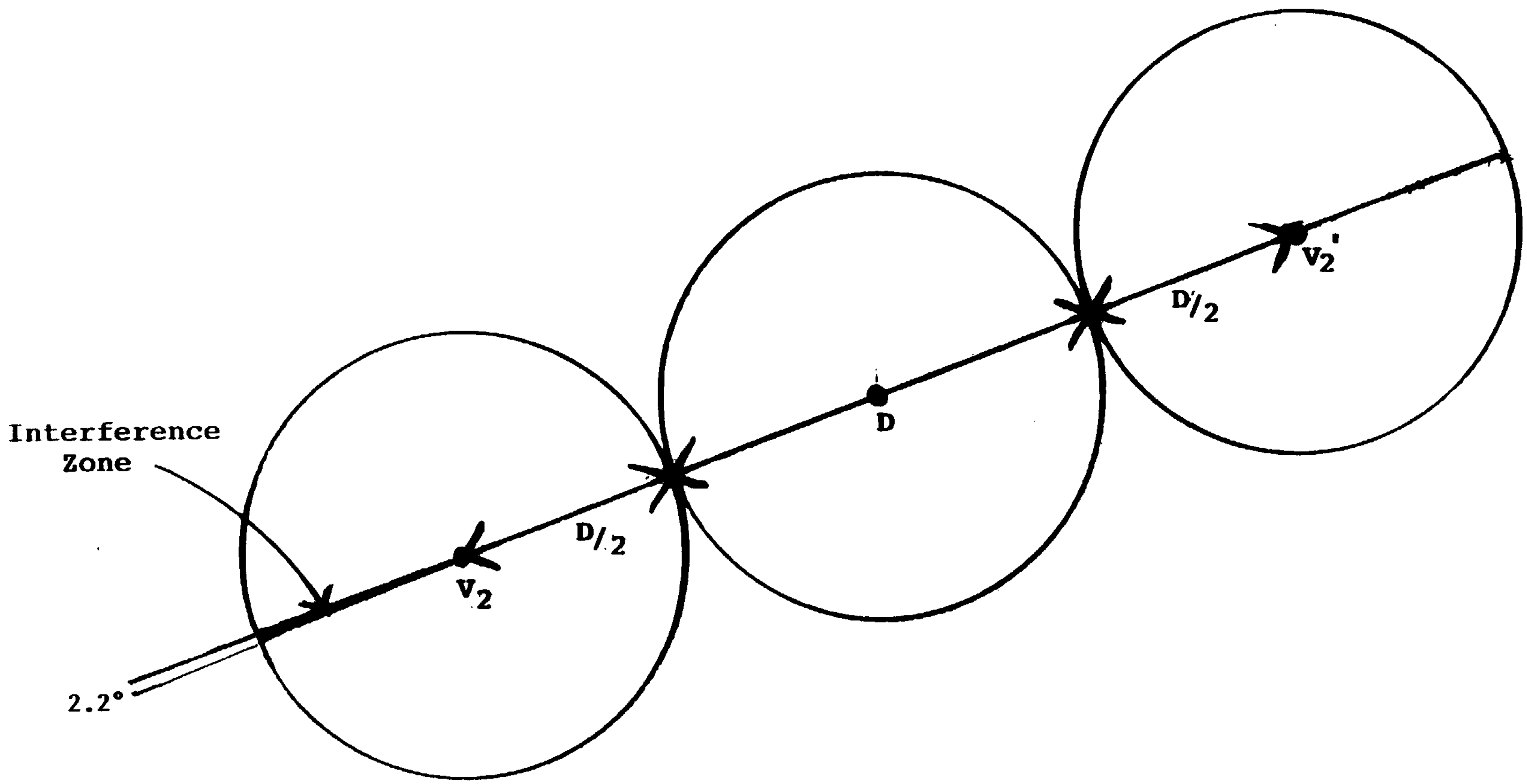


Figure 3. V_2/V_2' Interference Geometry

Table F. Summary of Cell to Cell Isolation Factors, Their Combined Carrier to Interference (C/I) Ratio and the Resulting Obtainable Picture Quality (Q).

Cell/ Cell Type	Example	Geometry (dB)	Cross-Pol. (dB)	Frequency Interleave (dB)	Antenna Sidelobe (dB)	C/I (dB)	Q	% Sites with Q=5
Lat-Long Adjacent								
Mainlobe	V_1/H_1	10	30	0	0	40	5	100
Sidelobe	V_1/H_1	10	30	0	26	66	5	100
Mainlobe	V_1/H_2	10	30	10	0	50	5	100
Sidelobe	V_1/H_2	10	30	10	26	76	5	100
Lat-Long Non-adjacent								
Mainlobe	V_2/V_2'	14	0	0	14	28	5	100
Sidelobe	V_2/V_2'	14	0	0	26	40	5	100
Diagonal Adjacent								
Mainlobe	V_1/V_2	10	0	10	14	34	5	100
Sidelobe	V_1/V_2	10	0	10	26	46	5	100
Diagonal Non-adjacent								
Mainlobe	V_2/V_2'	14	0	0	14	28	5	100
Sidelobe	V_2/V_2'	14	0	0	26	40	5	100

(a) Blockage and Earth Curvature

As with mobile cellular telephone systems, the presence of natural obstacles such as buildings, foliage, earth curvature and irregular terrain serves as a separator of the desired cell signal and those signals from different cells. This is accomplished by designing the elevation pattern of the transmitting antenna to point no higher in elevation than required for the intended transmission to recipients within the cell. In this way, the amount of signal from the cell radiated into other cells is minimized, and with it the potential for interference among cells. This is particularly true for transmissions characteristic of the 27.5 to 29.5 GHz band which undergo rapid attenuation outside the intended cell due to blockage imposed by physical obstacles.

Without blockage, the efficient use of spectrum for any cellular system designed to provide continuous coverage nationwide would not be possible. There would be too large a separation requirement before frequencies could be reused. In the case of cellular transmissions for mobile telephones the problem is actually much worse than for the LMDS cellular. For mobile, the subscriber is constantly moving, hence reliance on a favorable lie can not be made for very long. But with a fixed point to fixed point, local to multipoint distribution system, the subscriber is fixed with respect to the desired transmitter and likely interfering transmitters. Moreover, because he is fixed with respect to his own cell's transmitter, his antenna has a sharply focused pattern in its direction.

Nevertheless, blockage is highly path dependent. It is not amenable to as precise a formulation as frequency diversity, polarization or space (distance) isolation. On this subject, the CCIR Rep. 562-4, pg 353, Annex to Vol. V, CCIR 1990 [4], states:

> Measurements of broadcast transmissions at 12 GHz in the United States of America (Bentz, 1982) demonstrated

> the importance of line-of-sight paths for service in this band. In a hilly urban area of San Francisco, where 38% of the paths were obstructed by terrain or buildings, the obstructed paths had a median attenuation 20 dB greater than line-of-sight paths. At 60% of the obstructed sites, reflected signals were measured with a median level 3 dB greater than the median for other obstructed sites.

For specific paths, models for blockage effects are presented in CCIR Rep. 1146 (Vol. V), Reference [5]. However, while these effects in practical systems do serve a useful purpose in interference suppression between cells, for purposes of the LMDS design no isolation due to blockage has been assumed to this point. It is anticipated that this will prove to be a conservative approach considering the typical 20 dB of attenuation findings quoted in the CCIR reference cited.

The effects of earth curvature in placing the interference zone at or near the smooth earth radio horizon will also reduce the level of interference from the undesired LMDS source. Given the combined effects of blockage and radio horizon, the isolation between the desired and undesired LMDS signals is likely to significantly exceed the values used in **Table F** due to geometry.

(b) Receiver Level Control for FM Threshold Straddling

In areas where interference persists, it will be possible to utilize level control in the receiver to place the desired signal above the threshold of FM improvement in the demodulator and place the undesired signal below the FM threshold. By employing this technique, due the non-linear characteristic of the FM demodulator below the threshold of FM improvement, the interfering signal can be suppressed with no negative impact on picture quality. For example, consider the case where the subscriber antenna, desired LMDS transmitter and undesired LMDS transmitter (interference) are aligned in the receiver antenna boresight. In this case we expect a C/N of 29 dB at the edge of the cell in clear conditions, and a C/I of 14 dB if the high-gain antenna pointing technique is not employed. If the FM threshold is at approximately 8 dB above noise, which is a good estimate for the modulation index employed in the FM LMDS, 14 dB of attenuation would be placed in the receiver front end to reduce the interfering signal to a level 7 dB below the receiver threshold, while the desired carrier would be maintained 7 dB above the threshold. This would result in suppression of the interfering signal due to FM capture, and a C/N of 15 dB, which would give an S/N of 44 dB, yielding a Q rating better than the cable standard.

IV. Summary

In Section II, it was demonstrated that the Suite 12 LMDS signal produces a video S/N of at least 45 dB, even under rain-faded conditions at the edge of a cell. Under these conditions, a Q of approximately 4 is obtainable. A Q of 5 is obtainable under the vast majority of cases (all but 8 hours per year for 99.9% availability in fringe areas).

In Section III, it was shown that the combination of spatial separation of cells, frequency interleaving, polarization isolation, and antenna discrimination effects suppress co-channel interference between LMDS transmitters such that a Q of 5 is obtainable in 100 percent of receiver locations. Should receiver sites suffer from co-channel interference for any reason after these methods are applied, exploitation of the FM threshold characteristic by receiver level control and the effects of path blockage and earth curvature will likely eliminate any remaining co-channel interference.

Accordingly, it is clear that the Suite 12 design for cellular LMDS affords the spectral efficiency benefits of frequency reuse within each and every cell without cell-to-cell interference. Further, it is clear that the use of polarization isolation and frequency interleaving are essential to achieve the desired cell-to-cell interference ratios and to minimize LMDS interference with satellite systems.

References:

1. "Broadcasting Satellite Service, Measured Interference Protection Ratios for Planning Television Broadcasting Systems," CCIR Rep. 634-4, Annex to Vol. X/XI Part 2, XVIIth Plenary Assembly, Dusseldorf, 1990.

2. "Reference Data for Engineers: Radio, Electronics, Computers and Communications," 7th Edition, Howard W. Sams, 1985.

3. "Propagation Data and Prediction Methods Required for Terrestrial Line-of-Sight Systems," CCIR Rep. 338-6, page 365, Vol. V Annex, XVIIth Plenary Assembly, Dusseldorf 1990.

4. "Propagation Data Required for Terrestrial Broadcasting and Point-to-Multipoint Communications Systems in the Frequency Bands above 10 GHz," CCIR Rep. 562-4, page 352, Vol. V Annex, XVIIth Plenary Assembly, Dusseldorf, 1990.

5. "Terrain Scatter as a Factor in Interference," CCIR Rep. 1146, page 592, Vol. V annex, XVIIth Plenary Assembly, Dusseldorf 1990.

6. "Radio System Design for Telecommunications," Roger L. Freeman, John Wiley & Sons, Inc, NY 1987.

7. "Cellular Vision - Digital Modulation Analysis," prepared by Roger Freeman Associates, Nov. 5, 1993.

8. "Satellite Communication Systems Engineering," Pritchard Sciulli, Prentice Hall, 1986, pp. 358-365.

9. SUITE 12 SYSTEM ANALYSIS FOR VIDEO DISTRIBUTION AND SECONDARY SERVICES, a report prepared by David Sarnoff Research Center, Princeton, NJ; September 17, 1991 for Suite 12, 12 Dag Hammarskjold Boulevard, Freehold, New Jersey, 07728, Project Name: Brighton Beach, Task 2 Completion Report.

10. PETITION FOR RULEMAKING, filed by SUITE 12 GROUP, September 23, 1991.

11. COMMENTS OF SUITE 12 GROUP, CC Docket 92-297, March 16, 1993.

12. CCIR Report 634-4, page 561, paragraph 3.1.5; 1990 Reports of the CCIR: Annex to Vol. X, XI-Part 2.

Appendix A

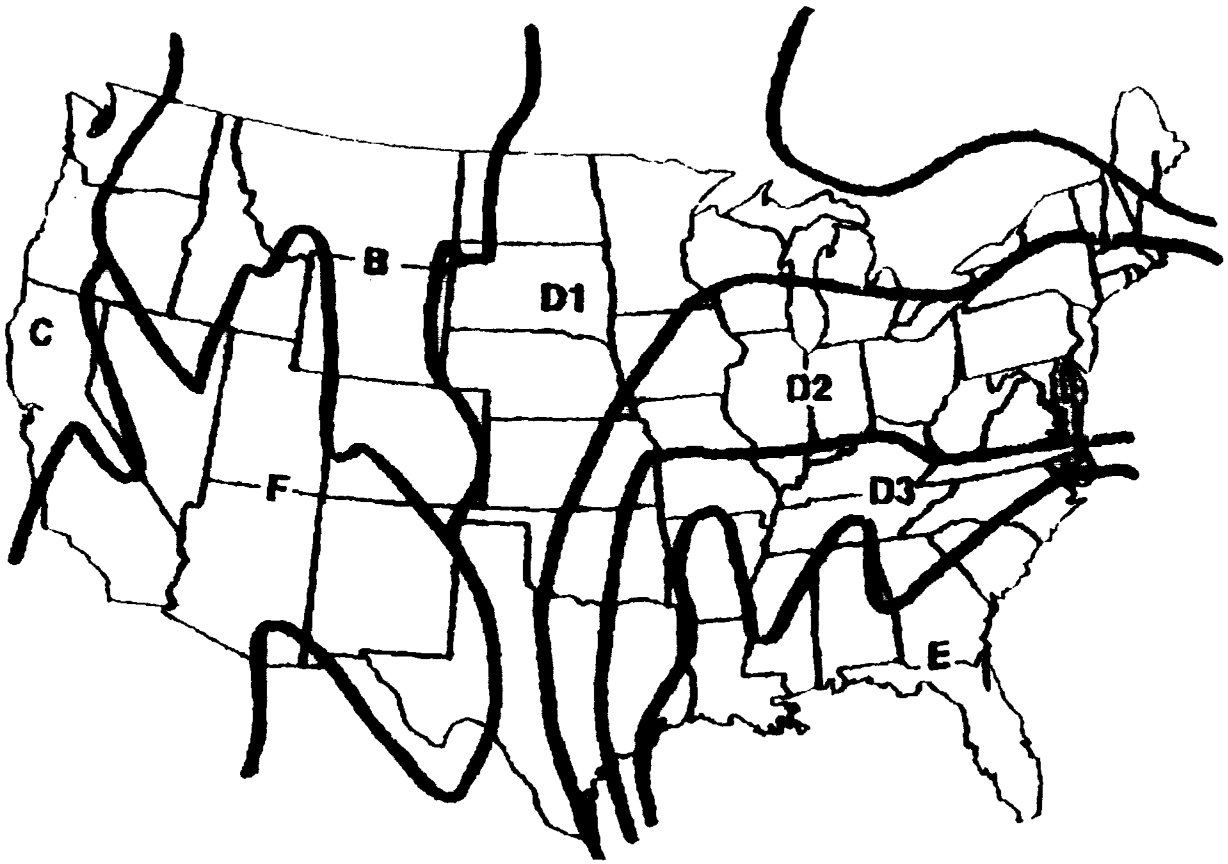
Calculation of Excess Attenuation due to Rainfall

To determine the path loss due to rainfall, CCIR report 721 is referenced using the rain rate region for New York on the following page (Attachment 1) can be seen that the New York area falls into region "D2" in the figure. Referring to Attachment 2, it can be seen that the rainfall rate for 99.9 percent availability, equivalent to a 0.1 percent excedence, is 15 mm/hr for region D2. Then, using the nomograph in Attachment 3, it can be seen that for a 15 mm/hr rain rate at 28 GHz, a specific attenuation of 2.7 dB per kilometer results.

This specific attenuation converts to a path loss due to rain of 13 dB for the three-mile path. This value is used in Section II to compute C/N for the LMDS system.

Note that this is a "worst case" value for rain attenuation because we have employed a constant rain rate model. That is, we have assumed that the rain rate over the entire three-mile path is a 15 mm/hr. In fact, for such rain rates, the "path averaged" rain rate in a statistical model (e.g., the Crane model) would be significantly smaller, resulting in a smaller rain attenuation and a higher C/N for rain-faded conditions.

GEOGRAPHIC REGIONS OF SIMILARITY IN RAINFALL STATISTICS
(From Crane and CCIR)



Region	mm/hr	Attenuation/mile	Area sq.mi.
F	5.5	1.5 dB	109
B	6.8	1.8 dB	92
C	7.2	2.0 dB	82
D1	11	3.2 dB	48
D2	15	4.6 dB	30
D3	22	6.7 dB	20
E	35	11.00 dB	9

Attachment 1